



Clinical Outcomes of Atypical Inflammatory Variants of Abdominal Aortic Aneurysm

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Background: Most abdominal aortic aneurysms are degenerative atherosclerotic aneurysms. Inflammatory or infected abdominal aortic aneurysms, which show a slightly different clinical course, are rarely encountered in clinical settings. Therefore, we aimed to investigate the clinical course of these variants of abdominal aortic aneurysms.

Methods: This retrospective study included 32 patients with atypical inflammatory or infected abdominal aortic aneurysms who underwent emergent graft replacement between November 1997 and December 2017. Patients were followed up at the outpatient clinic for a mean period of 4.9 ± 6.9 years. We analyzed the patients' clinical course and compared it with that of patients with atherosclerotic abdominal aortic aneurysms.

Results: There was 1 surgical mortality (3.0%) in a case complicated by aneurysmal free rupture. In 2 cases of infected abdominal aortic aneurysms, anastomotic complications developed immediately postoperatively. During the follow-up period, 10 patients (30%) developed graft complications, and 9 of them underwent reoperations; of these, 2 patients (22.2%) died of postoperative complications after the second operation, whereas 2 patients survived despite graft occlusion.

Conclusion: Patients with inflammatory abdominal aneurysms frequently develop postoperative graft complications requiring secondary surgical treatment, so they require close mandatory postoperative follow-up.

Keywords: Aorta, Surgery, Prosthesis, Infection

Introduction

Abdominal aortic aneurysm (AAA) is a degenerative disease with atherosclerotic pathology, and most patients with this disease have no complaint of any pain until impending rupture. However, in rare cases, these aneurysms are associated with abdominal pain without obvious rupture. These variants have a nonatherosclerotic pathology that involves a thick inflammatory adhesion to the surrounding tissue, thereby causing major difficulties when performing dissection during surgery. In some cases, the focal inflammatory adhesion forms an aorto-intestinal fistula, and its clinical course is quite different from that of ordinary degenerative atherosclerotic aneurysms. Moreover, a pus-like fluid is sometimes contained within the necrotic aneurysmal wall or around the aneurysm; thus,

the surgeon may be reluctant to use an artificial graft. These inflammatory lesions are difficult to identify before an urgent operation; thus, most surgeons only encounter these lesions accidentally and without any preparations. Most of these inflammatory lesions cause symptoms that prompt the patient to seek consultation at the hospital, subsequently resulting in urgent surgery. Moreover, in emergent operations for these atypical pathologic AAAs, it is difficult to perform adhesiolysis to expose the clamping site of the aorta, and there is a risk of damaging the surrounding organs.

In this study, we aimed to investigate the clinical course of these atypical AAAs.



Methods

Between November 1997 and September 2017, 276 patients with AAAs underwent open surgical replacement by 1 surgeon in Dong-A University Hospital. Among them, 32 patients (11.6%) were classified as having atypical AAAs, including 26 patients (9.4%) with chronic inflammatory AAAs and 6 patients (2.2%) with acutely infected AAAs. These variants were defined based on the operative findings, such as a thick adventitial adhesion around the aneurysm with a thickened aneurysmal wall (19 cases), a focal thick adhesion causing an aorto-intestinal fistula (6 cases), or a focal aneurysm containing odorless pus that drained from the aneurysmal wall in the absence of an atherosclerotic aortic wall (8 cases). Such findings were combined in some cases.

The clinical characteristics of patients, including surgical results and follow-up data, were analyzed using R ver. 3.6.1 (The R Foundation for Statistical Computing, Vienna, Austria; <https://www.r-project.org/>). Categorical data were analyzed with the chi-square test, while continuous data were analyzed with the t-test. The survival rate was analyzed using Kaplan-Meier curves and the log-rank test. A p-value <0.05 was considered to indicate statistical significance.

This study was reviewed and approved by the Institutional Review Board of Dong-A University Hospital (IRB approval no., DAUHIRB-20-024) and the requirement for informed consent was waived.

Results

Patient characteristics

Male patients were predominant (male:female=30:2), and the patients' mean age was 63.9±9.9 years (range, 51–79 years). Twenty-nine (90.6%) of the patients complained of abdominal pain, whereas, among patients with typical atherosclerotic AAA, only 73 (29.9%) complained of abdominal pain from impending or actual rupture. We followed up the patients at our outpatient clinic for a mean period of 4.9±6.9 years.

At our clinic, all symptomatic patients underwent urgent or emergent base graft replacement. Among the asymptomatic patients, the same operation was performed when the aneurysm diameter exceeded 5.5 cm or rapid growth was observed. Thus, most of the inflammatory AAA cases were treated with emergent graft replacement, including aortoiliac replacement in 21 patients, abdominal aortic replacement in 5 patients, aortobifemoral bypass graft in 5

patients, and thoracoabdominal aortic replacement in 1 patient. One of the aortoiliac replacement procedures was performed using bilateral superficial femoral veins; this procedure is known as the neo-aortoiliac system (NAIS). There were several combined procedures, including an internal iliac artery bypass in 3 patients, renal artery bypass in 1 patient, intestinal repair or reanastomosis in 5 patients, and omental flap coverage of the graft in 2 patients. To expose the aneurysmal neck, the thick adhesion around the left renal vein required sharp dissection in 10 patients. Among them, 6 patients needed renal vein division and reanastomosis after the proximal aortic anastomosis. Six patients needed a suprarenal aortic clamp (Table 1).

Surgical findings

The surgical findings included rigid adherence of the thickened adventitia to the surrounding organs (Table 2). The small intestine was the most common adherent organ, as observed in 19 patients (59.3%). Six patients with intestinal adhesive lesions developed an intestinal fistula. In 10 patients (31.2%), the renal vein adhered to the aorta, requiring sharp dissection to expose the proximal clamping site. There were 4 cases (12.5%) of vena cava adhesion and 4 cases (12.5%) of iliac vein adhesion with the aortic adventitia. These lesions also made the exposure of the clamping site difficult because of bleeding from the venous injury. There were 3 cases (9.3%) of a posterior fistula invading an intervertebral disc and 2 cases (6.2%) of ureteral adhesions that caused hydronephrosis, which were released after surgery.

Focal saccular aneurysms occurred in 12 patients (37.5%), of whom 6 developed fistulae with adhesive tissues and 4 developed pseudoaneurysms with a wall defect, which were very vulnerable to rupture.

Eight patients (25%) showed a pus-like fluid collection within the aneurysmal wall; of these, 6 were suspected of having an acute infection with a thin aneurysmal wall that was very friable to rupture and 3 were culture-positive. These 6 patients were classified as having infected AAA.

We cultured the aneurysmal wall fluid in all patients, although only 8 (25%) showed positive results; of these, *Salmonella* was found in 3 cases, *Staphylococcus* in 3, *Listeria monocytogenes* in 3, and Gram-positive cocci in one. Five of these patients had a chronic inflammatory type and 3 had an acutely infected type.

Table 1. Operative procedures

No.	Sex	Age (yr)	Vascular procedures	Aneurysm neck procedures	Intestinal procedures
1	M	69	Aortobifemoral bypass		Jejunal repair
2	M	59	Aortobifemoral bypass		Jejunal repair
3	M	59	Aortobiiliac replacement	Suprarenal clamping	
4	M	65	Aortobiiliac replacement	Renal vein division	
5	M	62	Aortobiiliac replacement		
6	M	66	Abdominal aortic replacement	Renal vein division	
7	M	53	Aortobifemoral bypass		Resection and reanastomosis
8	F	57	Aortobiiliac replacement		
9	M	50	Aortobiiliac replacement		Omental flap
10	M	64	Aortobiiliac replacement		
11	M	75	Aortobiiliac replacement+left internal iliac bypass	Renal vein sharp dissection	
12	M	63	Aortobiiliac replacement+right internal iliac bypass		
13	M	41	Abdominal aortic replacement		
14	M	82	Aortobiiliac replacement		Duodenal repair
15	M	52	Aortobiiliac replacement	Renal vein sharp dissection	
16	M	73	Aortobiiliac replacement	Suprarenal clamping	
17	M	75	Neo-aortoiliac system (trans-abdominal incision)		
18	M	61	Aortobiiliac replacement		
19	M	51	Abdominal aortic replacement		
20	M	63	Aortobiiliac replacement		
21	M	71	Aortobiiliac replacement+right renal artery bypass	Suprarenal clamping; renal vein division	
22	M	70	Aortobiiliac replacement	Renal vein sharp dissection	
23	M	66	Aorto-right femoral+left internal iliac artery bypass		
24	F	79	Aortobiiliac replacement	Supra-left renal clamping; renal vein division	
25	M	46	Abdominal aortic replacement		
26	M	73	Aortobiiliac replacement	Renal vein sharp dissection	
27	M	62	Aortobiiliac replacement		
28	M	71	Aortobiiliac replacement	Suprarenal clamping; renal vein division	Omental flap
29	M	73	Aortobiiliac replacement	Suprarenal clamping; renal vein division	
30	M	53	Thoracoabdominal aortic replacement		
31	M	64	Aortobifemoral bypass		
32	M	76	Aortobiiliac replacement		Resection and reanastomosis

M, male; F, female.

Postoperative in-hospital course

As shown in Table 3, the mean duration of hospitalization was 22.7 ± 18.5 days (range, 5–90 days). There was 1 surgical mortality (case 28), which was due to a cardiac arrest caused by massive bleeding of the free ruptured aneurysm during surgery, which resulted in severe hypoxic brain damage after resuscitation. One patient had late in-hospital mortality (case 17); this patient developed graft failure with a fistula in the vein graft at 2 months after surgery. Despite an attempt to perform coil embolization, the fistula remained present. The patient refused redo surgery and was discharged against medical advice.

Two infected AAA patients (cases 9 and 15) developed anastomotic pseudoaneurysms during the immediate postoperative period. Both had a friable thin wall with pus-like fluid accumulation. Both cases were repaired with redo surgery during hospitalization and discharged without sequelae. During follow-up, graft infection was not observed in these cases. However, case 9 had a recurrence of inter-graft pseudoaneurysm at 1.5 years after discharge, which was repaired with coil embolization [1].

Clinical course after discharge

Five patients were lost to follow-up, and the mean follow-

Table 2. Operative findings

No.	Adhesion site	Rupture or fistula	Saccular aneurysm	Pus	Culture	Type
1	Duodenum	Intestinal fistula	(+)			Chronic inflammation
2	Jejunum	Intestinal fistula				Chronic inflammation
3	Vertebra, inferior vena cava	Vertebral fistula	(+)			Chronic inflammation
4	Intestine, renal vein					Chronic inflammation
5	Intestine, colon, renal vein				Tuberculous meningitis	Chronic inflammation
6	Intestine, renal vein, mesentery				Coagulase (-) <i>Staphylococcus</i>	Chronic inflammation
7	Intestine, inferior vena cava	Intestinal fistula	(+)			Chronic inflammation
8	Intestine, ureter, retroperitoneum					Chronic inflammation
9	Mesentery	Impending rupture		(+)		Acute infection
10	Intestine		(+)			Chronic inflammation
11	Iliac vein, renal vein					Chronic inflammation
12	Iliac vein				<i>Salmonella</i>	Chronic inflammation
13	Intestine	Pseudoaneurysm, impending rupture	(+)			Chronic inflammation
14	Duodenum	Intestinal fistula	(+)			Chronic inflammation
15	Renal vein	Pseudoaneurysm, impending rupture	(+)	(+)	Coagulase (-) <i>Staphylococcus</i>	Acute infection
16	Mesentery, iliac vein				<i>Salmonella</i>	Chronic inflammation
17		Pseudoaneurysm, impending rupture	(+)	(+)		Acute infection
18	Retroperitoneum					Chronic inflammation
19	Vertebra	Vertebral fistula	(+)			Chronic inflammation
20	Intestine		(+)			Chronic inflammation
21	Intestine, renal vein					Chronic inflammation
22	Inferior vena cava, renal vein					Chronic inflammation
23	Intestine					Chronic inflammation
24	Retroperitoneum, inferior vena cava, renal vein			(+)	<i>Listeria monocytogenes</i>	Chronic inflammation
25	Intestine			(+)	<i>Salmonella</i>	Acute infection
26	Intestine, renal vein, both ureters					Chronic inflammation
27	Intestine, iliac vein			(+)	<i>Staphylococcus epidermidis</i>	Chronic inflammation
28	Duodenum, renal vein	Intestinal fistula, anterior rupture	(+)			Chronic inflammation
29	Renal vein	Pseudoaneurysm, impending rupture	(+)	(+)	Gram (+) cocci	Acute infection
30	Suprarenal area	Pseudoaneurysm, impending rupture		(+)		Acute infection
31	Retroperitoneum, intestine	Vertebral fistula				Chronic inflammation
32	Intestine	Intestinal fistula				Chronic inflammation

up period was 6.2 ± 3.5 years (range, 0.3–11.8 years) (Table 3). During the follow-up period, 4 of the 7 inflammatory AAA patients who required additional secondary procedures underwent an NAIS operation (cases 3, 5, 13, and 23) [2] and 3 patients underwent extra-anatomical bypass after removal of the infected graft (cases 2, 12, and 19) [3]. One of the patients who underwent an NAIS operation died from hypoglycemic shock immediately after the second

operation [4] (case 3). All 7 inflammatory AAA patients had no pus drained from the wall or showed negative results of the culture tests at the first operation. Two patients (cases 2 and 23) had an intestinal fistula. There were 2 patients (cases 13 and 19) of delayed graft occlusion among the reoperation cases, of whom 1 (case 13) was diagnosed with Behçet disease, but neither patient developed critical limb ischemia.

Table 3. The clinical course of inflammatory AAA

No.	Admission period (day)	In-hospital events	Post-discharge events	Interval (yr)	Results
1	47		Gastrointestinal bleeding	4.8	Death from gastrointestinal bleeding
2	15		Graft infection → graft takedown with axillobifemoral bypass	1.1	Improved
3	11		Graft infection → NAIS	1.0	Death from brain damage
5	15		Graft infection → NAIS	1.3	Improved
6			Lung cancer	2.9	Death from cancer
9 ^{a)}	90	Anastomotic pseudoaneurysm → thoracoabdominal aortic replacement (POD 65)	Anastomotic pseudoaneurysm → coil embolization → revision intestinal repair	4.9	Improved
12	19		Graft infection → removal of left limb of graft and femorofemoral bypass	4.7	Improved
13	13		Graft infection → NAIS	3.4	NAIS failure (improved)
14	21		Readmission due to sepsis	0.3	Death from sepsis
15 ^{a)}	49	Anastomotic pseudoaneurysm → graft replacement (POD 7)	Chronic renal failure; pneumonia	5.3	Death from pneumonia
17 ^{a)}	34	Vein graft fistula → coil embolization failure → refusal of open repair		0.2	Death from bleeding
18	24		Anastomotic pseudoaneurysm → thoracoabdominal aortic replacement	6.9	Death from bleeding in the second operation
19	11		Anastomotic internal fistula → graft takedown and axillobifemoral bypass	1.3	Axillofemoral bypass graft occlusion (improved)
23	10		Graft infection → NAIS	5.9	Improved
28	5	Cardiac arrest during operation → hypoxic brain damage			Death from surgery

AAA, abdominal aortic aneurysm; NAIS, neo-aortoiliac system; POD, postoperative day.

^{a)}Acute infected AAA.

Another inflammatory AAA patient (case 18) developed a delayed pseudoaneurysm and died during the second operation. There were 3 cases of non-surgical late death, which were due to lung cancer, sepsis, and pneumonia (cases 6, 14, and 15).

Comparison of the clinical characteristics between inflammatory or infected AAA and atherosclerotic AAA

As presented in Table 4, the inflammatory AAA patients were statistically significantly younger than the atherosclerotic AAA patients ($p=0.004$). Moreover, diabetes mellitus was more prevalent in the inflammatory AAA patients than in the atherosclerotic AAA patients ($p=0.026$). However, other clinical characteristics showed no statistically significant differences between the 2 groups.

The mean operative time of the inflammatory AAA patients was 214.0 ± 63.9 minutes, which was statistically significantly longer than that of the atherosclerotic AAA pa-

tients (164.5 ± 54.8 minutes). The 30-day surgical mortality and long-term mortality rates during follow-up were not significantly different between the 2 groups (Fig. 1).

The mean interval until the second operation was 3.3 ± 0.4 years (median, 4.7 ± 1.3 years) in the inflammatory AAA patients. Moreover, second surgical treatments due to graft problems were performed more frequently in the inflammatory AAA patients than in the atherosclerotic AAA patients (Fig. 2).

Discussion

Inflammatory AAA was first reported in 1972 by Walker et al. [4], who found that 10% of 187 cases of AAA had the following 3 key distinguishable features: (1) marked wall thickening, (2) thick fibrosis of the adjacent retroperitoneum, and (3) rigid adherence of the adjacent structure to the anterior aneurysm wall. However, their report on inflammatory AAA did not draw much attention in the field of surgery. The prevalence of inflammatory AAA was esti-

Table 4. Clinical characteristics of inflammatory AAA and atherosclerotic AAA

Characteristic	Inflammatory AAA (n=32)	Atherosclerotic AAA (n=244)	p-value
Age (yr)	64.2±9.9	69.4±8.95	0.008
Sex			0.355
Male	29	201	
Female	3	43	
Symptomatic	29 (90.6)	73 (29.9)	0.001
Diabetes mellitus	11 (34.3)	40 (16.4)	0.026
Hypertension	17 (53.1)	142 (58.2)	0.722
Smoking	12 (37.5)	90 (36.9)	1.000
Chronic kidney disease	3 (9.3)	19 (7.8)	1.000
Chronic obstructive pulmonary disease	1 (3.1)	13 (5.3)	0.916
Cerebrovascular accident	5 (15.6)	32 (13.1)	0.908
Ischemic heart disease	4 (12.5)	55 (22.5)	0.283
Peripheral arterial occlusive disease	6 (18.8)	21 (8.6)	0.134
Rupture	7 (21.9)	48 (19.7)	0.954
Shock	2 (6.3)	21 (8.6)	0.909
Operative time (min)	214.0±63.9	164.5±54.8	0.001
Transfusion (unit)	10.8±11.4	9.0±14.0	0.448
Admission period (day)	29±379	17±14	0.085
30-Day mortality	1 (3.1)	25 (10.2)	0.329
Overall mortality	8 (25)	37 (15.2)	0.245
Graft problem requiring reoperation	11 (34.4)	10 (4.1)	0.001
Reoperation due to graft infection	7 (21.8)	1 (0.4)	

Values are presented as mean±standard deviation or number (%). AAA, abdominal aortic aneurysm.

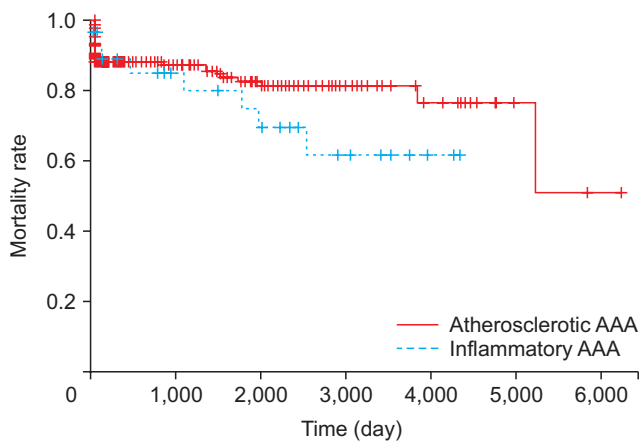


Fig. 1. Comparison of the long-term survival curves. It was analyzed using the log-rank test (p=0.3). AAA, abdominal aortic aneurysm.

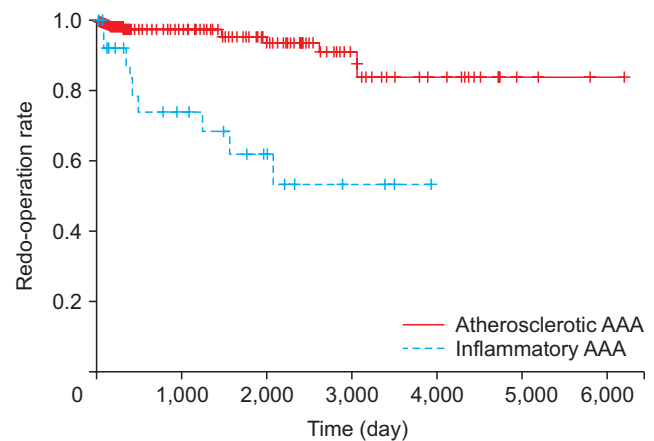


Fig. 2. Comparison of the redo-operation-free curves. It was analyzed using the log-rank test (p<0.001). AAA, abdominal aortic aneurysm.

mated to be approximately 5%–10% of all cases of AAA [5]. Patients with inflammatory AAA were reported to be much younger than those with atherosclerotic AAA [6], which was also confirmed in our study. Furthermore, inflammatory AAA patients were more likely to be symptomatic, causing them to seek medical attention earlier than those with asymptomatic atherosclerotic AAA.

An extraordinary saccular expansion of the adventitia due to the presence of inflammation also distinguishes inflammatory AAA from ordinary atherosclerotic AAA. The normal portion of the aorta in AAA is also atherosclerotic in cases of atherosclerotic AAA, but the inflammatory saccular aneurysm usually shows no pathologic findings in the normal portion of the aorta. Such saccular inflamma-

tion tends to form a fistula with adherent organs. Aortic fistulae are more common in cases of inflammatory AAA than in cases of atherosclerotic AAA [7]. The free rupture of inflammatory AAA is rare; instead, most of these cases develop a fistula to the adherent organ. In our case series, 6 inflammatory AAA cases developed intestinal fistulae, and only 1 case of anterior free wall rupture of a saccular aneurysm was found. Most inflammatory AAA cases are usually detected before rupture due to the presence of abdominal pain that is not related to an impending or obvious rupture.

Unlike patients with atherosclerotic AAA, most patients with inflammatory AAA have an elevated erythrocyte sedimentation rate or abnormalities in other serum inflammatory markers that reflect systemic inflammation. Computed tomography (CT) and magnetic resonance imaging are both sensitive modalities used to demonstrate the cuff of soft tissue inflammation surrounding the aneurysm, which is a characteristic feature of inflammatory AAA. However, in an urgent situation, preoperative CT detection of inflammatory AAA is not always possible, and it is difficult to distinguish inflammatory AAA from the impending rupture of atherosclerotic AAA. Thus, most of our patients were confirmed to have inflammatory AAA during urgent surgery.

An infected AAA can result from degenerative changes caused by a primary infection of a normal aortic wall or from a secondary infection of an atherosclerotic AAA. Primary infected AAA is quite rare, with an incidence of <1%, and the secondary infection of atherosclerotic AAA is also uncommon [8]. In our data, only 6 patients (2.2%) were diagnosed with infected AAA. Infected AAA is also difficult to diagnose or differentiate from inflammatory AAA preoperatively [9], and the surgeon is likely to only encounter the infected AAA in the operative field during urgent surgery, without any preparation. Infected AAA usually appears in a saccular form and has a tendency to exhibit a rapidly changing clinical course. Five of our cases involved pseudoaneurysms with an impending rupture. Preoperative antibiotic therapy is optimal as a treatment option, but sometimes immediate surgery is required for rapidly growing aneurysms. Two patients in our study (cases 9 and 15) developed an anastomotic pseudoaneurysm in the immediate postoperative period and required additional graft replacement. This complication was not related to the infection, but rather to the fragile wall of the aneurysm; thus, a more meticulous and secure anastomotic technique is needed.

Although these atypical variants of inflammatory AAA

are rare, surgeons cannot avoid encountering such lesions in the emergent surgical field. Thus, surgeons should always be prepared for the possibility of encountering such lesions when operating on symptomatic AAA patients.

The transperitoneal approach was chosen in all patients, except 1 patient who underwent thoracoabdominal aortic replacement. The first stage of surgery for AAA involves exposing the aneurysmal neck to clamp the inflow, after which the outflow iliac arteries should be exposed. The thick adherent organs in the inflammatory AAA are vulnerable to injury during adhesiolysis. The small intestine (especially the duodenum), vena cava, and the ureter are the organs that are frequently injured [6], leading to an increased mortality risk [10]. Minimal adhesiolysis of these organs and meticulous sharp dissection can reduce the possibility of such complications. Surgical mortality has decreased in recent decades from 12.5% to 5% [11]. In our study, there was no significant difference in in-hospital mortality between inflammatory AAA and atherosclerotic AAA patients, but the operative time was longer in the inflammatory AAA group than in the atherosclerotic AAA group, due to the need for meticulous dissection of the adhesion in patients with inflammatory AAA. Steroids were not administered before or after the operation.

During the follow-up period, late graft complications developed more frequently in the inflammatory AAA patients than in the atherosclerotic AAA patients. These complications resulted in redo operations and late mortality. Graft infections were the main complication that required reoperation. The cause of late graft infections was unknown. Although diabetes was more prevalent in the inflammatory AAA group, only 1 patient (case 3) who required a second operation due to graft infection had diabetes, and he died of hypoglycemic brain injury after the second operation. In no cases did an acutely infected AAA cause delayed graft infection.

The NAIS operation is our procedure of choice for graft infections in the abdomen, and 4 of the 7 patients with a late graft infection underwent NAIS operations [12]. We have previously reported one of these cases with a specific description of the procedure [2]. In 1 patient with a late graft infection (case 13), disappearance of the graft was observed, but collateral branches were found. The patient did not develop limb ischemia, but was diagnosed with Behçet disease. One patient with an infected AAA (case 17) underwent a primary NAIS operation due to odorous pus draining from the pseudoaneurysm wall. We were reluctant to use an artificial graft in such a contaminated operative field.

In conclusion, the atypical variants of inflammatory or infected AAA were detected early (i.e., before rupture), and the patients with these AAAs underwent urgent surgery due to the associated symptom of abdominal pain. Acute infected AAA was considered to cause graft infection after the graft replacement, but most graft infections developed in patients with chronic inflammatory AAA. In contrast, the acutely infected AAA patients developed anastomotic pseudoaneurysms in the immediate postoperative period. Therefore, more meticulous anastomosis will be needed in patients with acutely infected AAA, and close follow-up for graft complications will be needed in chronic inflammatory AAA cases.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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